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**Aggregate Resources Inventory of
Hindon and Anson
Geographic Townships
Haliburton County**

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Aggregate Resources Inventory
Paper 151

By Staff of the Engineering and Terrain Geology Section,
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GEOLOGICAL MAP (back pocket)

1.	Sand and Gravel Resources, Hindon and Anson Geographic Townships, Scale 1:50 000.	
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Abstract

This report includes an inventory and an evaluation of sand and gravel resources, as well as a discussion of bed-rock aggregate potential, for Hindon and Anson geographic townships in Haliburton County, southern Ontario. The report is based on a detailed field assessment undertaken in the summer of 1990 and on previous studies of the area. The investigation was conducted to delineate and determine the quality and quantity of aggregate within the area to help ensure that sufficient aggregate resources are available for future use.

In general, the townships contain only limited resources of high-specification aggregates. Most of these resources are concentrated in 3 Selected Sand and Gravel Resource Areas. These Resource Areas occupy an available area of approximately 170 ha and contain an estimated 12 million tonnes of sand and gravel. In addition, numerous deposits have been classified as resources of secondary significance which add considerably to the resource base of the area.

The aggregate in the report area is generally suitable for most usual applications, however, use of the material in hot-laid asphalt may be restricted in places by the presence of brittle and friable gneiss and schist within the gravel. In addition, the Ministry of Transportation will not accept local gravel for use in Portland cement concrete that will be exposed to de-icing salts. There is a bonding problem between the aggregate and cement which results in concrete deterioration.

The project area is underlain by Precambrian bed-rock of the Canadian Shield. Recrystallized and deformed gneisses are the most widespread rock type. The bedrock in the area can exhibit wide variations with respect to aggregate quality, consequently, site specific testing is recommended prior to extraction.

Selected Resource Areas are not meant to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

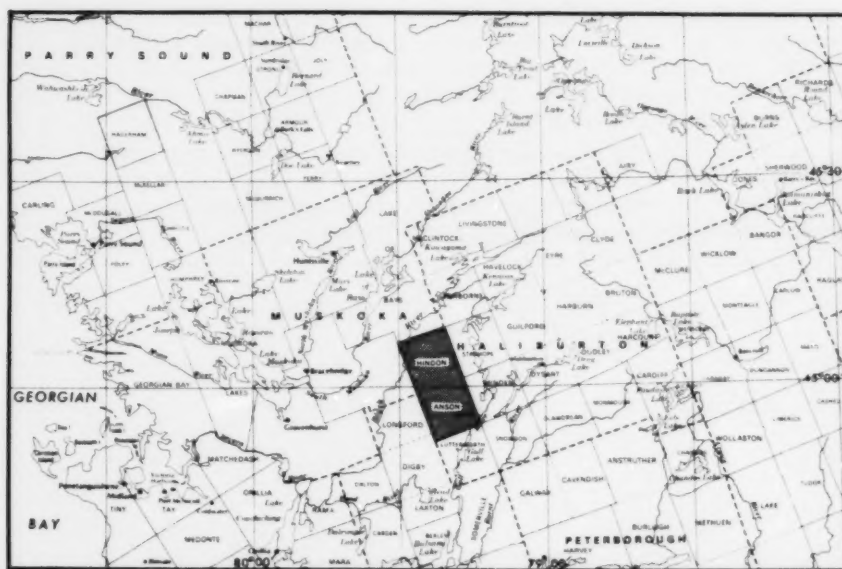


Figure 1. Key map showing the location of Hindon and Anson geographic townships, Haliburton County, scale 1:1 800 000.

Résumé

Ce rapport comprend un inventaire et une évaluation des ressources en sable et en gravier, ainsi qu'un exposé sur le potentiel en agrégat du substratum des cantons géographiques de Hindon et Anson dans le comté de Haliburton, sud de l'Ontario. Ce rapport est basé sur une évaluation détaillée faite sur le terrain au cours de l'été 1990 et sur des études préalables du secteur. Cette étude a été entreprise dans le but de délimiter la présence d'agrégat dans le secteur et d'en déterminer la qualité et la quantité afin de s'assurer que les ressources en agrégat disponibles sont suffisantes pour des utilisations futures.

D'une manière générale, ces cantons ne possèdent que des quantités limitées d'agrégat de qualité supérieure. La plupart de ces ressources sont concentrées dans trois zones sélectionnées pour leurs ressources en sable et en gravier. Ces zones de ressources occupent une zone disponible d'environ 170 ha et contiennent approximativement 12 millions de tonnes de sable et gravier. De plus, de nombreux dépôts ont été classés comme ressources d'importance secondaire ce qui ajoute considérablement à la base de ressources de ce secteur.

L'agrégat dans le secteur étudié convient généralement pour la plupart des applications habituelles. Cependant, l'utilisation de ce matériau pour l'asphalte répandu à chaud risque d'être limité par la présence, par endroit, de gneiss et de schiste cassants et friables dans le gravier. Par ailleurs, le ministère des Transports n'acceptera pas l'emploi de gravier de provenance locale dans la fabrication du béton à base de ciment Portland qui sera exposé aux sels de dégivrage. Il existe un problème de liaison entre l'agrégat et le ciment qui entraîne une détérioration du béton.

Le socle rocheux précambrien du Bouclier canadien se trouve dans la totalité du secteur étudié. Des gneiss recristallisés et déformés constituent le type de roche le plus courant. Dans ce secteur, la qualité de l'agrégat varie beaucoup selon le type de roche du substratum. En conséquence, il est recommandé d'étudier chaque site plus en détail avant de procéder à l'extraction.

Les zones sélectionnées pour leurs ressources ne sont pas destinées à un usage unique et permanent. Elles représentent des zones dans lesquelles une ressource importante a été reconnue et peuvent être réservées entièrement ou partiellement pour l'exploitation et/ou comme réserves de ressources.

Cette publication est disponible en anglais seulement.

Aggregate Resources Inventory of Hindon and Anson Geographic Townships Haliburton County

By Staff¹ of the Engineering and Terrain Geology Section

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Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1987, the total tonnage of mineral aggregates extracted was 156 million tons (142 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Northern Development and Mines 1989).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas

experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of the resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential for bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see *References*) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative sections in these deposits are sampled in 11 to 45 kg units from existing pit faces or from test pits. The samples are analyzed for grain size distribution, and in some cases the Los Angeles abrasion and impact test, absorption, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Ontario Ministry of Transportation, or in the Geoscience Laboratory, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The locations of additional sources were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The co-operation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50000. These base maps are prepared by the Land and Resource Information Branch, Ontario Ministry of Natural Resources with information taken from maps of the National Topographic System by permission of Energy, Mines and Resources Canada, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in hectares. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Tonnage values can then be calculated by multiplying the volume of the deposit by 17 700 (the density factor). This factor is approximately the number of tonnes in a 1 m thick layer of sand and gravel, 1 ha in extent, assuming an average density of 1770 kg/m³.

$$\text{Tonnage} = \text{Area} \times \text{Thickness} \times \text{Density Factor}$$

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e., original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of hectares unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g., wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 17 700) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however, the aggregate potential of these deposits is discussed in the report.

UNITS AND DEFINITIONS

The measurements and other primary data available for resource tonnage calculations are given in Metric units in the text and on the tables which accompany the report. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (*see* Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

MAP 1: SAND AND GRAVEL RESOURCES

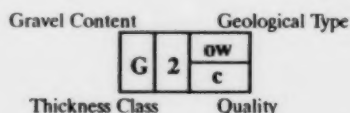
Map 1 shows the extent and quality of sand and gravel deposits within the study area and an evaluation of the aggregate resources. The map is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete.

The present level of extractive activity is also indicated on Map 1. Sand and gravel pits are identified by a numbered dot on the map and described in Table 2. Each description notes the estimated face height of the pit and the estimated percentage of gravel it contains.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the maps. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies an outwash deposit 3 to 6 m thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:



SELECTED SAND AND GRAVEL RESOURCE AREAS

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by dark red shading on Map 1.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units. They represent areas in which a major resource is known to exist, and may be reserved wholly or partially for extractive development and/or resource protection.

Deposits of secondary significance are indicated by medium red shading on Map 1. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered part of the aggregate supply of the area.

Areas of tertiary significance are indicated by light red shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of

criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the project area. Generally, deposits in Class 1 (greater than 6 m thick), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in areas with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols. They are: gravel content (G or S), fines (C), oversize (O), and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road subbase aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 10 cm in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable

oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation (MTO) and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 4, where the results of MTO quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendixes B and D, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular A and Granular B Type 1; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The con-straining effect of legally required setbacks surrounding such features is included in the evaluation. A

quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a project area should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, an area that has large resources in comparison to its surrounding region constitutes a regionally significant resource area.

Areas with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

BEDROCK RESOURCES

Precambrian shield rocks are generally more complex and variable than Paleozoic rocks. They often show wide variations in mineralogy, texture (grain size), joint patterns and degree of weathering, even within specific rock types and over relatively short distances. As these factors are considered important in determining the suitability of the bedrock for use as aggregate, the aggregate potential may also vary considerably from location to location.

Careful selection is especially important if the bedrock is to be used as concrete aggregate. Deleterious chemical reactions may develop in the concrete which can lead to its eventual deterioration. Fortunately, these chemical reactions should not influence the use of bedrock-derived aggregate for such uses as roadbase material. However, highly weathered, very porous and friable rock should be avoided for all uses.

For these reasons, no specific bedrock resources have been selected for resource protection. A summary of the bedrock resources on a regional level is included in the Bedrock Geology and Resource Potential section.

Part III — Assessment of Aggregate Resources in Hindon and Anson Geographic Townships

LOCATION AND POPULATION

Hindon and Anson geographic townships are located along the western border of Haliburton County in southern Ontario. The townships occupy approximately 35 000 ha. The area is covered by the Bracebridge (31 E/3), Haliburton (31 E/2) and Minden (31 D/15) map sheets of the National Topographic System, at a scale of 1:50 000.

The geographic townships form part of the larger Township Municipality of Anson, Hindon and Minden. The population of this municipality was 2683 in 1988 (Ontario Ministry of Municipal Affairs 1991). Most of the population is concentrated in the community of Minden which is located along the southeastern border of Anson geographic township. Outside of the community of Minden, the report area is sparsely populated. A significant seasonal population exists along the shores of Bob, Brady and Big Orillia lakes.

Access in the area is provided by a system of township roads developed near the community of Minden and off of King's Highway 118. Elsewhere in the townships, road access is generally poor and limited to a small number of cottage and forest access roads.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The terrain in the area has been divided into two physiographic regions by Chapman and Putnam (1984). Most of Hindon geographic township is included within the Algonquin Highlands — a large region where bedrock knobs and ridges are interspersed with areas of varying thickness of till or other glacial deposits. The terrain of the Georgian Bay Fringe dominates Anson geographic township and is characterized by very shallow drift and exposed bedrock.

The glacial deposits in the area are related to the last major advance and melting of a continental ice sheet during the Late Wisconsinan Substage of the Pleistocene Epoch (informally known as the "Great Ice Age"). As glacial ice advanced in a southerly to south-westerly direction over the project area, a discontinuous cover of till was deposited (Mollard 1980; Kaszycki 1987). This stony, silty sand to sand till generally exists as a thin veneer over bedrock, although in several areas significant thicknesses of till were observed. These thicker till accumulations often flank bedrock knobs or are found associated with drumlins. Till is usually not well suited for aggregate use as it often contains excess fines and abundant oversize clasts, however, it may be a suitable source of fill in some localities.

Several deposits of undifferentiated ice-contact stratified drift were deposited close to the ice front as it

melted. These deposits originated in a variety of depositional environments and are typified by a hummocky topography. Eskers, a type of ice-contact feature, were deposited by meltwaters flowing through tunnels under the ice or in re-entrants at the ice front. These eskers are in the form of segmented, sinuous ridges in the northeast corner of the report area. Ice-contact deposits generally consist of stratified sand and gravel and can exhibit wide variations in terms of aggregate quality and grain size distribution.

The outwash features in the report area were deposited by glacial meltwaters flowing in bedrock valleys beyond the ice-margin. Outwash deposits are situated in valleys presently occupied by Anson and Austin creeks and the Black River. The outwash material consists primarily of well-stratified and uniformly bedded sand and gravel. Those deposits designated by the dual designation of ice-contact — outwash on Map 1 exhibit characteristics of both deposit types.

As the ice front receded, low-lying areas were inundated by glacial lake waters. These areas include the Gull River valley and a low-lying area located just northwest of Minden (Kaszycki 1985). Where meltwaters entered the lakes directly from tunnels under the ice, subaqueous fans were formed (Rust and Romanelli 1975; Kaszycki 1985, in prep.). These fans consist of variable material ranging from fine sand to coarse gravel. Variable amounts of silt and clay may also be present in these deposits. Glaciolacustrine deltas were formed where glaciofluvial systems entered the lakes. These deltas are relatively flat features with steep frontal slopes. They consist largely of well stratified, gravelly sand. Glaciolacustrine plain sediments, consisting of silt and clay, were deposited in the deep parts of the glacial lakes. In the shallower parts of the lakes, predominantly silty fine sand was deposited. These glaciolacustrine sands are generally too fine for most aggregate uses except fill.

Erosional activity has been minimal since the disappearance of the ice sheet and the lowering of lake waters to present day levels. Organic deposits have developed in surface depressions and alluvium has been deposited along the courses of creeks and rivers.

EXTRACTIVE ACTIVITY

Most of the sand and gravel pits developed within the area are situated near the community of Minden, in Anson geographic township, or along forest and cottage access roads in Hindon geographic township. The pits have been opened to meet the demands associated with road construction and maintenance, cottage construction, residential and retail developments in Minden, and other general construction uses.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates the deposits which contain granular materials. These deposits occupy a total of approximately 1360 ha and contain an original resource tonnage of 73 million tonnes. Many of these deposits have limited potential for extraction because of the restricted amount of aggregate, poor quality of the aggregate, and/or poor resource accessibility. Consequently, only the most significant sources have been suggested for possible resource protection.

The deposits selected at the primary level of significance have been grouped into 3 Selected Sand and Gravel Resource Areas. The deposits contain aggregate resources considered potentially suitable for the production of road subbase. Variable amounts of coarse gravel suitable for crushing may also be available. In addition, several deposits have been selected at the secondary level. They are generally sand deposits which are considered potentially suitable for at least the production of Select Subgrade Material (SSM).

The Selected Sand and Gravel Resource Areas of primary significance occupy a total area of 203 ha. Cultural constraints and previous extraction reduce the area currently available to 170 ha. The areas contain possible sand and gravel resources of approximately 12 million tonnes.

Selected Sand and Gravel Resource Area 1

Nine deposits situated southwest of Pine Springs in Hindon geographic township are included in Selected Sand and Gravel Resource Area 1. The northernmost ice-contact deposit has been designated as Area 1a. Three pits have been opened in this deposit. Faces in pit no. 9 exposed 6 to 8 m of fine to coarse sand with isolated pockets of fine to medium gravel. The sand is also interbedded with silt layers in the eastern faces of the pit. A depth of 1.5 m of sand is revealed in the faces in the northern part of pit no. 12. In pit no. 11, up to 2 m of fine to coarse gravel overlies medium sand with some silty fine sand units. Limited amounts of Granular B Type I may be produced with selective extraction of the coarser aggregate units within the deposit. The sand appears best suited for SSM and other low grade uses. Area 1b is expected to contain similar quality aggregate as that described for Area 1a.

Pit no. 10 has been developed in the outwash deposit which constitutes Area 1c. Faces in the pit revealed 2 m of fine to medium gravel over 2 m of fine to coarse sand with some silty fine sand units. A sample taken from the upper gravel unit contained 39% gravel, 60% sand and 1% fines (Figure 3a). The aggregate in the pit appears well suited for the production of Granular B Type I.

Two esker deposits constitute Area 1d and are potential sources of coarse, crushable gravel. The

southern faces of pit no. 12, in the northern esker segment, revealed 2.5 m of medium to coarse gravel with a dirty sand matrix. Similar material may be available from the southern esker segment. Detailed subsurface investigation is recommended prior to extraction in the southern esker as subsurface information is lacking and deposit boundaries have been based largely on airphoto interpretation.

Crushable gravel is also potentially available from Area 1e. Ridges, 2 to 5 m high, are common in this ice-contact deposit. Two test pits were excavated into the crests of these ridges. One test pit revealed 0.8 m of coarse gravel with abundant boulders, whereas the other uncovered 1 m of medium to coarse gravel. Both test pits were excavated in the southernmost tip of the area. Because of the variable relief of the deposit and the possible existence of bedrock close to the surface, detailed subsurface investigation is required to identify areas best suited for extractive development.

Area 1f consists of 2 ice-contact - outwash deposits situated along Austin Creek. Coarse gravel with abundant oversize material was observed at the surface of these deposits and also within a 1.2 m deep test pit excavated in the northern deposit. The material is considered well suited for crushing, however, a high water table may restrict extraction below 2 m.

The southernmost outwash - ice-contact deposit has been designated as Area 1g. Pit no. 13 has been opened in the deposit and faces revealed 1.5 m of medium gravel. The gravel content in the pit was estimated to be 50% and most of the gravel was in the 2.5 to 5 cm size range. This material appears well suited for the production of pit-run and crusher-run aggregates.

Resource Area 1 occupies a total of 98 ha. Cultural constraints and previous extraction reduce the area currently available to 89 ha. Assuming average thicknesses ranging from 1.8 to 5.5 m, aggregate resources are estimated to be 4.3 million tonnes. The northern part of Area 1 is readily accessible via a major forest access road, whereas, logging trails provide the only access in the south.

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 consists of 3 subaqueous fans and 3 ice-contact deposits located near the community of Minden in Anson geographic township. The subaqueous fan deposits have been designated as Areas 2a to 2c on Map 2. The material within subaqueous fan deposits often becomes coarser at depth. This relationship is evident in pit nos. 20 and 21 which have been opened in the two northernmost deposits, Areas 2a and 2b. Faces in pit no. 20 revealed between 1.2 to 3 m of fine to medium sand overlying less than 6 m of medium to coarse gravel with abundant oversize material. This lower gravel unit was sampled and contained 82% gravel, 17% sand and 1% fines (Figure 3a). Pit no. 21 is worked in two levels. The upper level

revealed 6 m of silty fine to medium sand. Up to 5 m of medium gravel is exposed in the lower level of the pit. A 1.5 to 2.5 m layer of silt and clay overlies the sand in the northern faces of the pit. The lower gravel units, in both pit nos. 20 and 21, are considered well suited for crushing purposes. Low-specification sand products, including SSM, are the most readily produced aggregates from the upper sand units. One pit has been developed in Area 2c. Faces in pit no. 25 revealed 1.5 to 2.5 m of gravelly sand which appears suitable for use as Granular B Type I. Selective extraction may be necessary in all 3 fan deposits to avoid excessively fine materials and/or for the production of high-specification aggregates.

The 3 southern ice-contact deposits have been designated as Areas 2d and 2e. Pit nos. 26 and 27 have been opened in Area 2d. The 3 to 8 m high faces in pit no. 26 consisted largely of silty fine to medium sand. Previous extraction has depleted much of the pit's reserves of coarse gravel. Coarse crushable gravel, with abundant oversize clasts, is exposed in the 3 m faces of pit no. 27. A sample of this material contained 72% gravel, 27% sand and 1% fines (Figure 4a). The gravel contained a high percentage of friable and brittle gneisses which may restrict some high-specification uses of the aggregate. A high water table may limit the depth of extraction in the southern parts of Area 2d. Area 2e is a 6 to 9 m high ridge along which several small excavations (pit no. 29) have been opened. The 2.5 to 6 m deep excavations exposed material ranging from silty fine sand to coarse, crushable gravel. A sample taken from one of the excavations contained 61% gravel, 38% sand and 1% fines (Figure 4a). A wide variety of aggregate products could be produced from Area 2e with selective extraction and sand control measures.

Resource Area 2 occupies 96 ha, of which 72 ha are currently available for extraction. Assuming average deposit thicknesses that range from 3.7 to 6.1 m, sand and gravel resources are estimated to total 6.7 million tonnes. The resource area is well situated with respect to the existing road network and to Minden, which is an important market for local aggregates.

Selected Sand and Gravel Resource Area 3

A subaqueous fan deposit located along the eastern boundary of Anson geographic township has been selected as Sand and Gravel Resource Area 3. The deposit extends eastward into Minden geographic township where it has also been selected for resource protection (Ontario Geological Survey 1988). Although sand is the predominant material exposed at the surface of Resource Area 3, pockets of gravel suitable for high-specification uses may occur at depth.

Resource Area 3 covers 9.0 ha, all of which is available for extraction. Assuming an average deposit thickness of 6.1 m, aggregate resources are approximately 1.0 million tonnes. The resource area is readily accessible by township roads.

Resource Areas of Secondary Significance

Six outwash sand deposits along the Black River, in the northwest corner of Hindon geographic township, have been selected at the secondary level of significance. Medium sand, suitable for SSM, is the dominant material in these deposits. There are, however, localized areas of gravelly, medium to coarse sand suitable for use as road subbase. This coarser material is often concentrated near the surface of the deposits and the material becomes finer at depth. The 3 pits identified in these deposits have been developed in aggregate which contains these relatively coarse units. In pit no. 1, a 0.5 m thick layer of fine to medium gravel overlies 1.2 m of fine to medium sand. Very silty fine sand is exposed in the pit floor. Medium to coarse sand with 10 to 15% gravel is revealed in the 1.0 to 1.5 m faces in pit nos. 3 and 4. A high water table in the area of pit no. 4 may limit extraction at greater depths.

A gravel outwash deposit in the northwest corner of Hindon geographic township has also been selected at the secondary level. Faces in pit no. 2, which has been opened in the deposit, exposed 1.5 to 2.5 m of medium to coarse gravel with pockets of silty fine sand. Similar material may be available from the undeveloped parts of the deposit, however, extraction may be inhibited by the deposit's proximity to cottages along Big Orillia Lake.

Four outwash deposits near Pine Springs, in the northeast corner of the report area, have been designated as secondary resources. These deposits consist predominantly of silty fine to medium sand (Van Luit et al. 1984) suitable for use as SSM or fill. Pockets of coarse material, suitable for higher specification uses, may occur locally in those deposits. A high water table may limit extraction in parts of these deposits.

Similar quality aggregate is potentially available from the 2 outwash deposits situated near Brady Lake in Hindon geographic township. The northern deposit may have the highest potential as an aggregate source since it contains slightly coarser material. Faces in pit no. 17 consisted of 3 m of medium to coarse sand with approximately 10% fine gravel which appears marginal for use as Granular B Type I. Medium sand with silty fine sand layers is exposed in the 2.5 m faces of pit no. 18 which has been opened in the southern feature.

The remaining areas selected at the secondary level include 6 deposits located northwest of Minden in Anson geographic township. The deposits are complex features exhibiting characteristics of both glaciolacustrine plains and subaqueous fans. The predominant sediment exposed at the surface of these deposits is silty fine to medium sand. SSM may be the most readily produced aggregate product from the deposits. Based on other subaqueous fan deposits in the area, these features may contain localized pockets or layers of coarser granular material. Therefore, further subsurface investigation may identify higher potential aggregate resources within these features.

BEDROCK GEOLOGY AND RESOURCE POTENTIAL

The bedrock in the report area is part of the Grenville Province of the Canadian Shield. The rocks of Precambrian age in the report area are subdivided into two major lithotectonic terranes (Wynne-Edwards 1972). Most of the report area is underlain by bedrock of the Central Gneiss Belt. The predominant rock types within this belt are highly deformed, commonly interlayered quartzofeldspathic and mafic gneisses. Large bodies of felsic igneous rocks are also situated within this belt. The southeastern corner of Anson geographic township is underlain by marble of the Central Metasedimentary Belt. A zone of tectonites and gneisses, which separates the two belts, is known as the Central Metasedimentary Belt Boundary Zone (Easton 1988).

In general, the bedrock geology of the area is extremely complex. Metamorphic and deformational processes are the main causes of this complexity (Marmont and Johnston 1987). The bedrock geology of the area is portrayed at a reconnaissance level in Figure 2. Geological mapping and reports by Satterly (1943), Davidson and Morgan (1981), Martin (1983), Easton (1987, 1988) and the Ontario Geological Survey (1991) cover portions of the project area. However, much of the northern part of the report area has not been mapped in detail.

The bedrock within the project area may exhibit wide variations, with respect to aggregate quality, over relatively short distances. Consequently, any site proposed for quarry development should be tested in detail before extraction occurs. Most of the area is underlain by more massive, hard and durable rock which appears suitable for a variety of aggregate applications. However, highly weathered, brittle and friable bedrock, which is unacceptable for aggregate, may occur in localized areas within the report area. As well, some of the massive, coarse-grained felsic igneous rocks and quartzofeldspathic gneisses with high mica, feldspar and quartz contents may have bonding problems because the smooth cleavage and fracture surfaces of these minerals hinder the adhesion of asphalt and cement mixes. This problem may be circumvented by weathering the rocks for a period of time in stockpiles or by adding chemicals which erode the smooth surfaces and allow better adhesion. Rogers (1985) reports that some granitic rocks can slowly react with the alkalis from Portland cement concrete, resulting in concrete deterioration. Within the report area, considerable latitude exists in choosing sites for potential bedrock extraction since there are extensive areas where bedrock is exposed at the surface or is covered by thin drift.

AGGREGATE QUALITY AND SUITABILITY

During field investigation, 4 samples were taken from existing pit faces. The samples were analyzed for grain

size distribution (Figures 3a to 4b) and 3 aggregate quality tests were performed. These tests include absorption and Magnesium Sulphate Soundness tests, as well as petrographic analysis. The results of these tests are portrayed in Table 4. The grain size analyses and quality tests were performed in the laboratories of the Ministry of Transportation (MTO), Downsview.

In general, the aggregate in the report area is considered to be of sufficient quality for uses including Granular A, B Type I and M. Higher specification uses of the aggregate, however, may be limited in some localities by the presence of friable and brittle gneissic particles within the gravel. These brittle and friable particles can give high Los Angeles abrasion and impact losses. MTO recognized that although Los Angeles abrasion and impact test results were high in Haliburton County, the aggregate was generally performing well in asphalt pavements in the field. Consequently, MTO modified their specifications for aggregate taken from the area to permit a loss of up to 50% instead of the usual 35% loss (Rogers 1985). Similarly, MTO increased the maximum petrographic number, from 160 to 180, for HL No. 4 aggregate.

The results of the quality tests performed on 3 of the samples were within the modified specification limits for HL No. 4 coarse aggregate. However, the fourth sample from pit no. 27 still did not meet the petrographic criteria for use in HL No. 4 asphalt. This high value is attributed to the relatively high concentration of weathered and friable gneisses in this pit.

Although an aggregate may meet specifications, the local gravels are not accepted by MTO for use in Portland cement concrete that will be exposed to de-icing salts. There can be a bonding problem between the cement and gravel which results in spalling of the concrete. Consequently, calcareous aggregate imported from the south has been used for bridge structures in the county. The aggregate in the area may also contain mica fragments (derived from the local bedrock) which do not bond well with cement mixes.

SUMMARY

The sand and gravel deposits in the report area are the product of glacial activity which occurred during the Late Wisconsin Substage of the Pleistocene Epoch. A number of these deposits, which contain significant resources of sand and gravel, have been grouped together into 3 primary resource areas. In addition, numerous deposits of secondary significance, which add considerably to the project area's resource base, have been selected. Care should be taken to ensure the continued availability of as much of the resource areas as possible.

In general, the report area contains only limited resources of high-specification aggregates. Those deposits selected at the primary level contain most of the report area's potential resources of crushable gravel and Granular B Type I aggregate. The secondary deposits are primarily sources of sand suitable for use as SSM or other low grade uses.

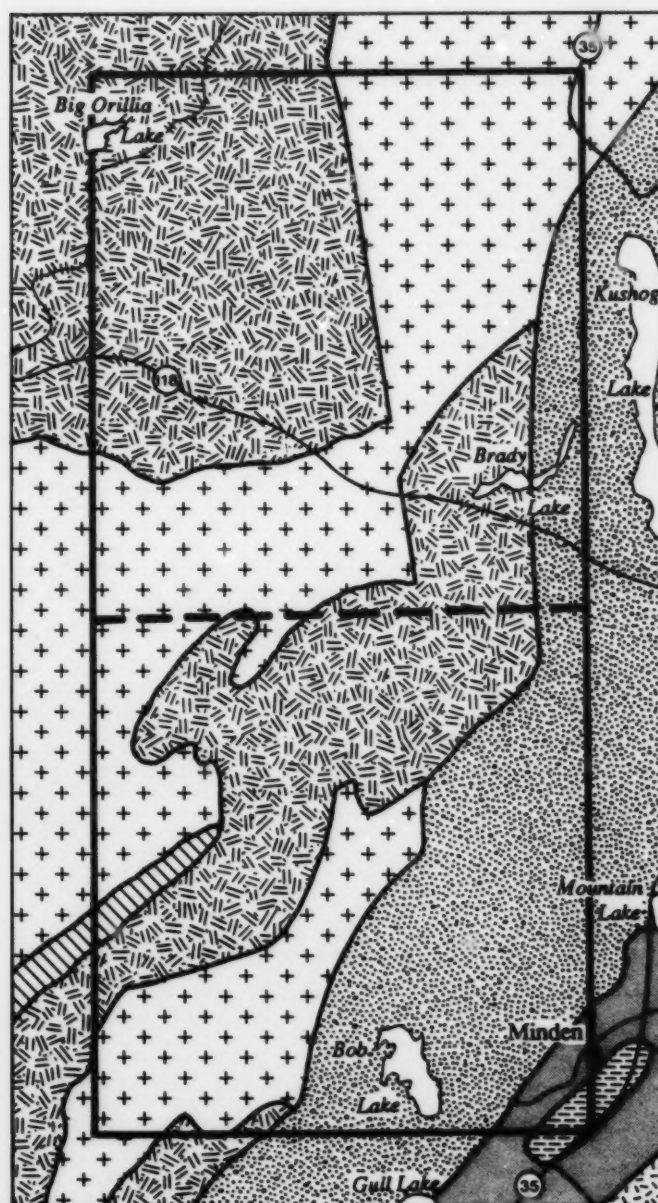
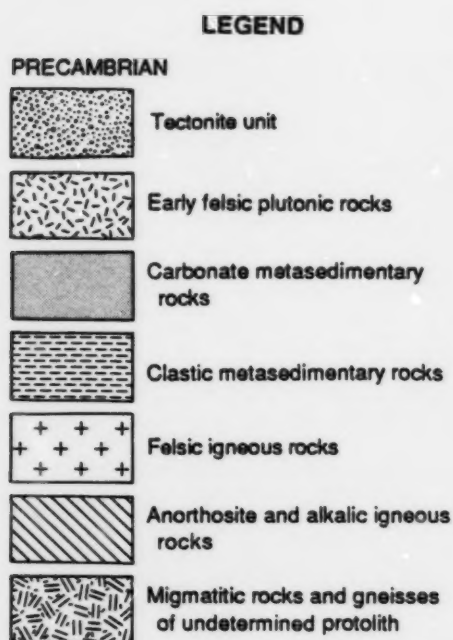


Figure 2. Bedrock geology of Hindon and Anson geographic townships, scale 1:180 000 (after Ontario Geological Survey 1991).

Precambrian-age bedrock of the Canadian Shield underlies the project area. Gneisses, felsic igneous rocks and tectonites are the predominant rock types in the townships. The bedrock in the area can exhibit wide variations in aggregate quality. Consequently, site specific testing is recommended prior to extraction.

Enquiries regarding the Aggregate Resources Inventory of Hindon and Anson Geographic Townships

should be directed to the Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, 7th Floor, 77 Grenville Street, Toronto, Ontario, M7A 1W4 [Tel: (416) 965-1663], or to the Resident Geologist, Ministry of Northern Development and Mines, P.O. Box 190, Dorset, Ontario, P0A 1E0 [Tel: (705) 766-2494], or to Minden District, Ministry of Natural Resources, Minden, Ontario, K0M 2K0 [Tel: (705) 286-1521].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

1	2	3	4	1	2	3	4
CLASS NO.	DEPOSIT TYPE (see Appendix C)	AREAL EXTENT Hectares	ORIGINAL TONNAGE Millions of Tonnes	CLASS NO.	DEPOSIT TYPE (see Appendix C)	AREAL EXTENT Hectares	ORIGINAL TONNAGE Millions of Tonnes
Hindon Geographic Township					S-LP-SF	146	16
2	G-OW	6.0	0.4		S-OW-LD	1.0	0.1
	S-OW	44	2.8		S-SF	17	1.8
	S-OW-IC	18	1.8		S-SF-LP	6.1	0.7
3	G-E	2.5	0.1	2	G-IC	26	1.7
	G-IC-OW	41	1.6		G-SF	16	1.3
	G-OW	8	0.3		S-LD	120	9.7
	G-OW-IC	12	0.4		S-LP-SF	47	3.8
	S-IC	5.0	0.2		S-OW	12	1.0
	S-IC-OW	3.2	0.1		S-SF	5.0	0.4
	S-LD	19	0.6		S-SF-LP	4.1	0.3
	S-OW	206	7.8	3	G-IC	4.5	0.2
	S-OW-IC	21	0.9		S-LP	64	2.8
4	G-IC	1.0	<0.1		S-OW	20	0.9
	S-AL	152	3.3		S-SF	19	0.7
	S-IC-OW	9.1	0.2	4	S-LD	4.3	0.1
	S-OW	212	4.6		S-LP	32	0.7
		760	25		S-OW	9.2	0.2
Anson Geographic Township						600	48
1	G-IC	35	3.8				
	G-SF	14	1.5	TOTAL FOR REPORT AREA:		1360	73

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

1 NO.	2 MTO NO.	3 FACE HEIGHT Metres	4 % GRAVEL	5 REMARKS
Hindon Geographic Township				
1	-	1.5-2.5	15	frequent silt seams
2	-	1.5-2.5	35-50	gravel with pockets of fine sand
3	-	1.5	15	water on pit floor
4	-	1	10	water on pit floor
5	-	1.5	35-40	near depletion
6	-	1.5-2.5	< 10	
7	-	2.5-4.5	< 20	near depletion, bedrock exposed in face
8	-	1.5-2.5	< 20	near depletion
9	H2-35	6-8	< 5	silt seams in eastern faces of pit
10	-	3.5	20-40	gravel concentrated in upper 2 m of pit faces
11	-	1.5-4	10-40	gravel concentrated in upper 1 to 2 m of pit faces
12	-	1-2.5	10-55	gravel concentrated in an esker ridge in the southern faces of the pit
13	-	1.5	50	crushable
14	-	1.5	< 10	near depletion
15	-	1.5-2.5	< 10	sand with seams of silt and gravel, near depletion
16	-	1	0	fine to medium sand
17	-	3	10	medium to coarse sand with fine gravel
18	-	2.5	0	medium sand with some silty fine sand units, water on pit floor
19	-	-	-	sand depleted to bedrock
Anson Geographic Township				
20	M20-11	4.5-7.5	0-65	sand concentrated in upper part of pit faces
21	M20-58	10	0-65	pit worked in two levels, gravel concentrated in lower level, and with some silt and clay in upper level, water on pit floor
22	-	10	0	overgrown
23	-	6	0	sand with frequent silt seams
24	-	-	-	sand depleted to bedrock

TABLE 2. SAND AND GRAVEL PITS, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

1 NO.	2 MTO NO.	3 FACE HEIGHT Metres	4 % GRAVEL	5 REMARKS
25	-	1.5-2.5	20	
26	-	3-8	0-50	variable from fine sand with silt seams to crushable gravel
27	M20-88	3	60-70	crushable gravel, abundant oversize clasts
28	-	1-3	-	till, overgrown
29	M20-76	2.5-6	20-50	variable from sand to crushable gravel
30	-	1	0	silty fine to medium sand

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

1 DEPOSIT NO.	2 AREA Hectares	3 CULTURAL SETBACKS Hectares	4 EXTRACTED AREA Hectares	5 AVAILABLE AREA Hectares	6 ESTIMATED DEPOSIT THICKNESS Metres	7 AVAILABLE AGGREGATE Millions of Tonnes
Hindon Geographic Township						
1a	18	5	1	12	5.5	1.2
1b	17	2	0	15	2.4	0.6
1c	6.0	-	-	6.0	3.7	0.4
1d	2.5	-	0.5	2.0	2.4	0.1
1e	28	-	-	28	2.4	1.2
1f	13	-	-	13	1.8	0.4
1g	13	-	-	13	1.8	0.4
	98	7.0	1.5	89		4.3
Anson Geographic Township						
2a	14	4.0	1.0	9.0	6.1	1.0
2b	16	-	1.0	15	4.6	1.2
2c	5.0	-	-	5.0	4.6	0.4
2d	26	3.0	10	13	3.7	0.9
2e	35	4.0	1.0	30	6.1	3.2
	96	11	13	72		6.7
3	9.0	-	-	9.0	6.1	1.0
TOTAL FOR REPORT AREA:	203	18	14	170		12

TABLE 4. RESULTS OF AGGREGATE QUALITY TESTS, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

Sample No.	COARSE AGGREGATE				FINE AGGREGATE
	<u>Petrographic Number</u>		Magnesium Sulphate Soundness (% Loss)	Absorption (%)	Magnesium Sulphate Soundness (% Loss)
	Granular & 16 mm Crushed	Hot Mix & Concrete			
Pit 10	113	151	5	.70	-
Pit 20	106	130	5	.54	11
Pit 27	127	193	7	.74	18
Pit 29	113	148	6	.87	18

NOTE: The results of the quality tests refer strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits, care should be exercised in extrapolating such information to the rest of the deposit. See Appendix D for descriptions of the tests and quality requirements for major aggregate products.

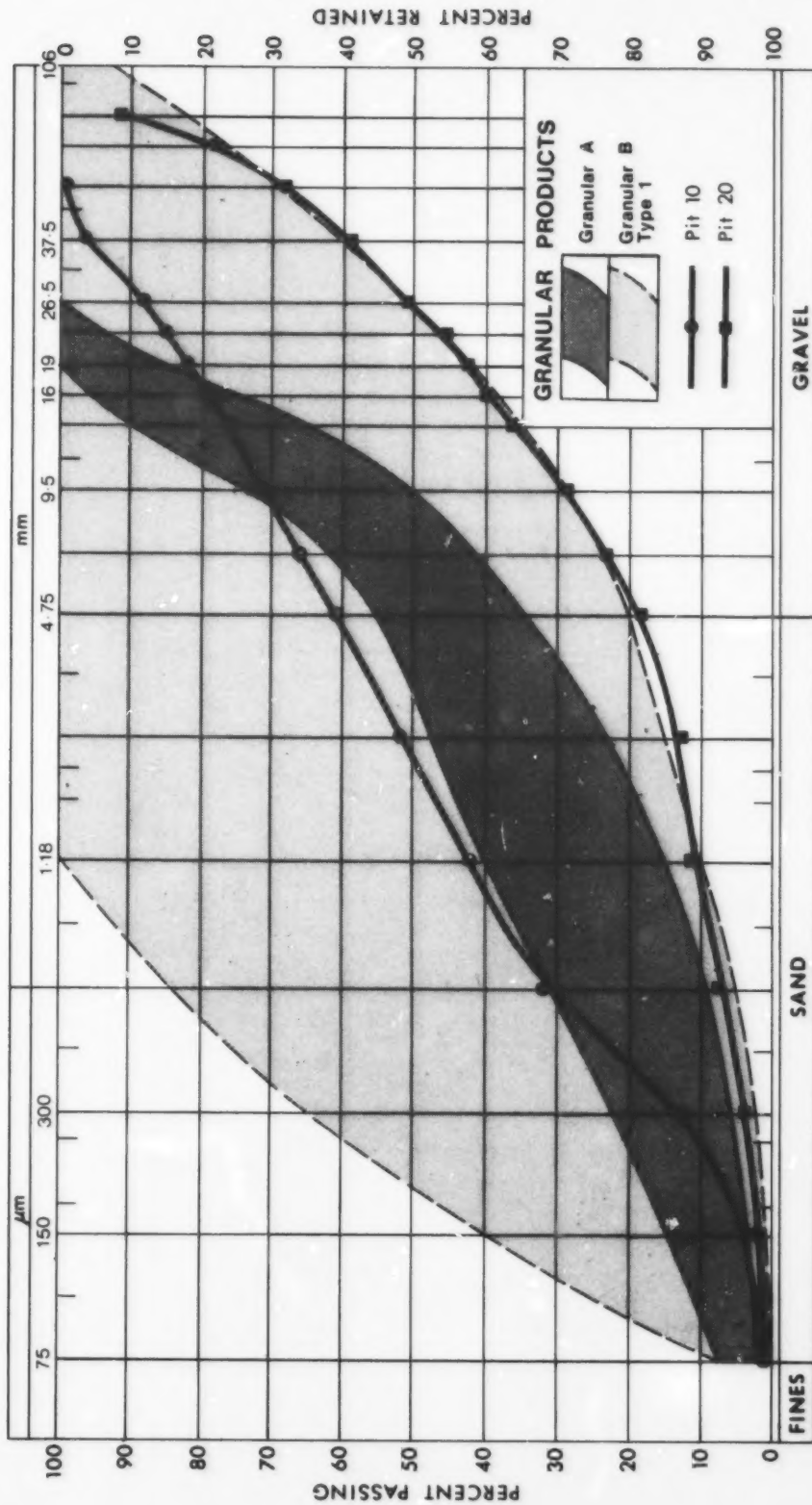


FIGURE 3a. AGGREGATE GRADING CURVES, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1010, 1988).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

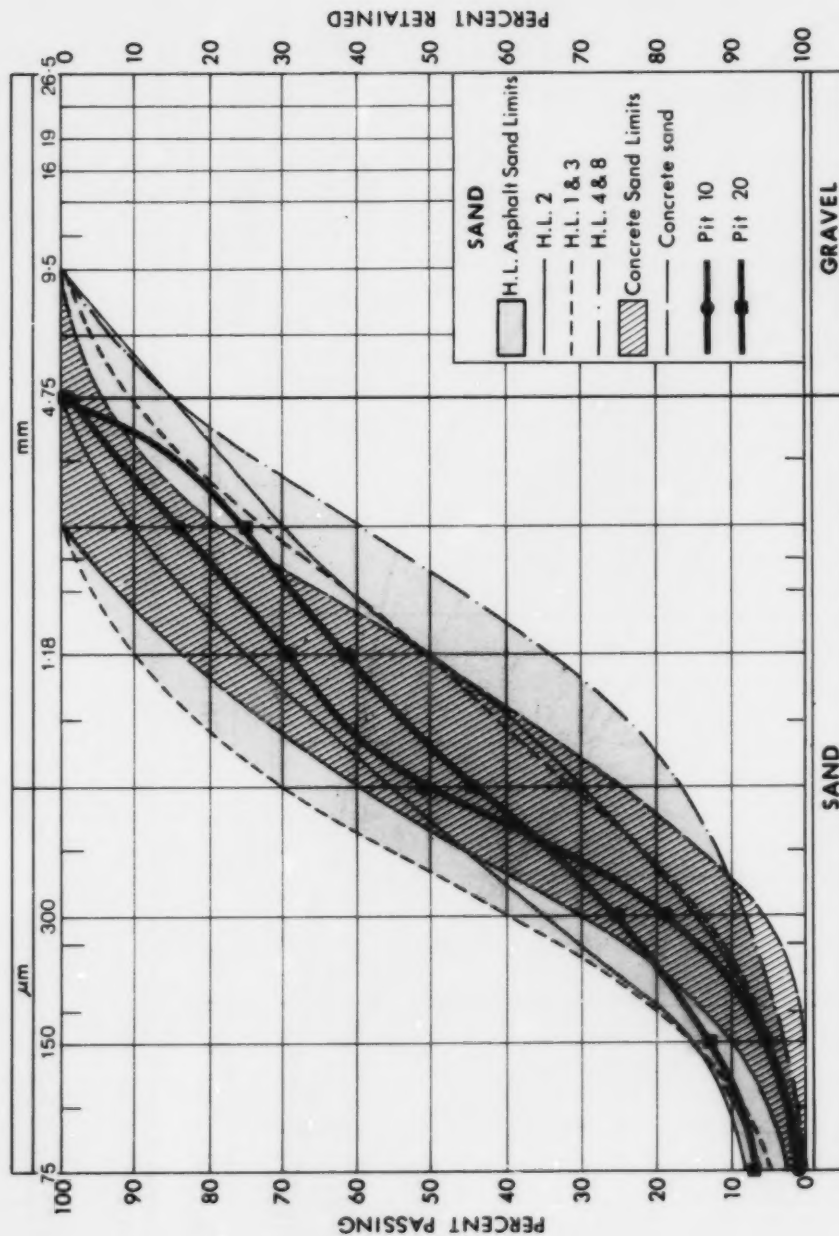


FIGURE 3b. AGGREGATE GRADING CURVES, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

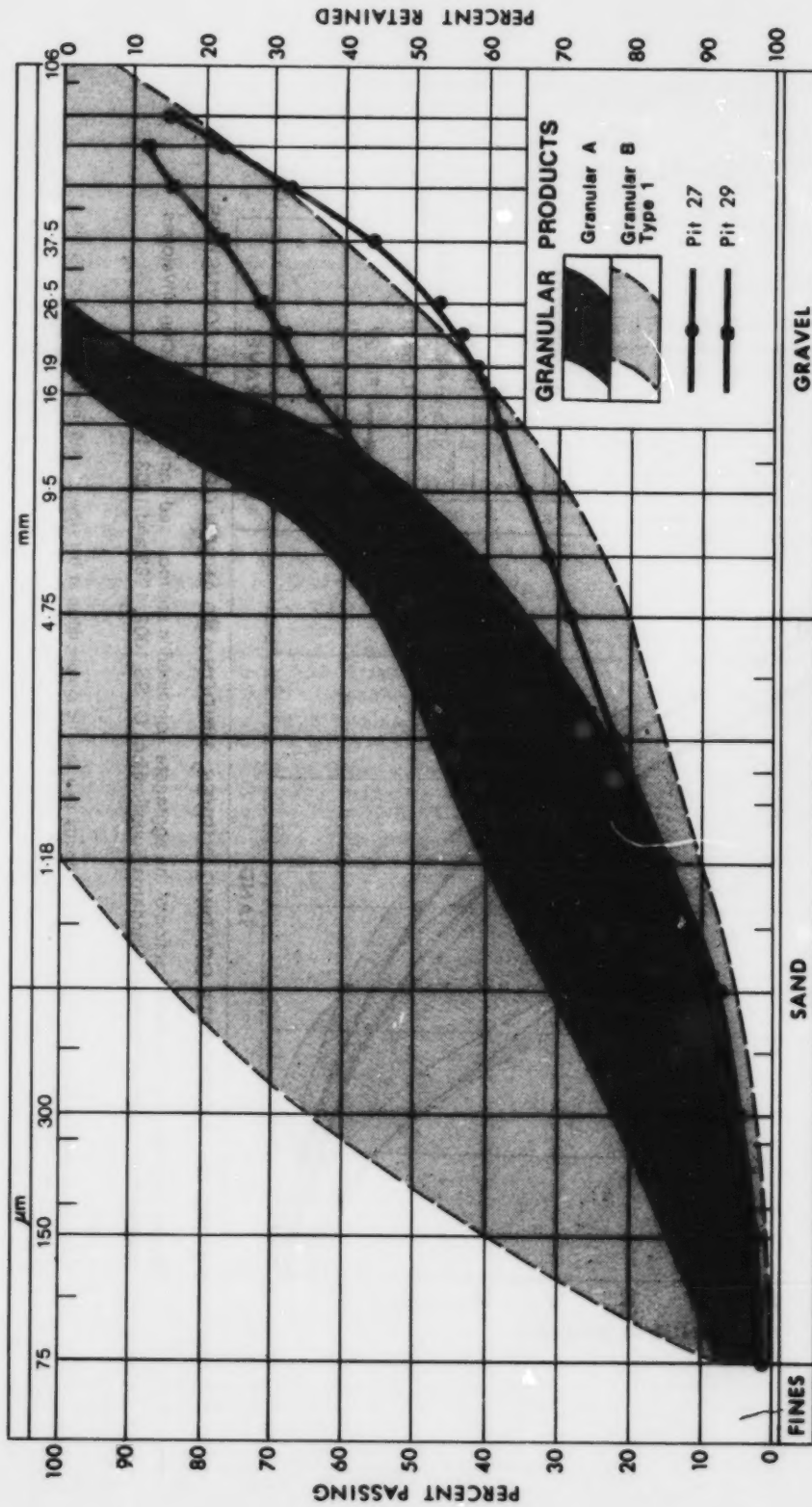


FIGURE 4a. AGGREGATE GRADING CURVES, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1010, 1988).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

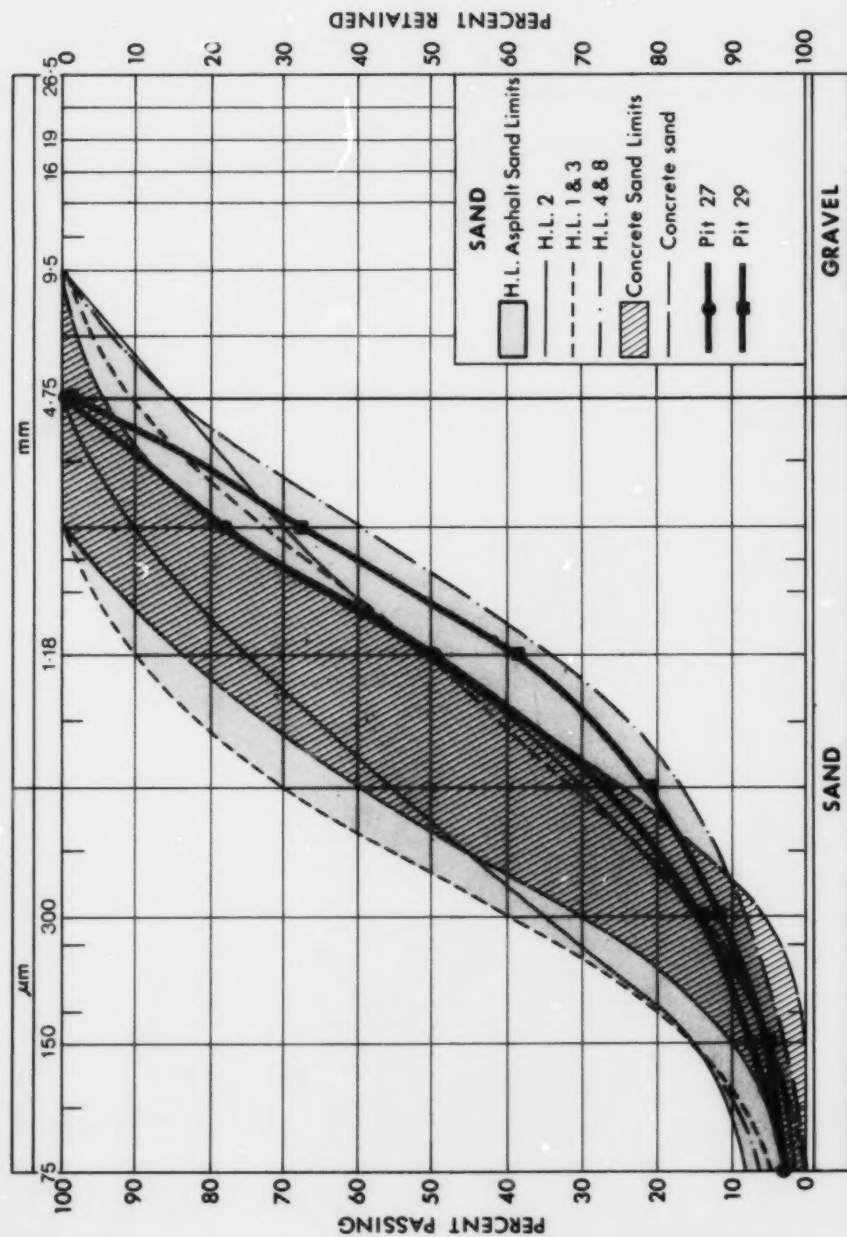


FIGURE 4b. AGGREGATE GRADING CURVES, HINDON AND ANSON GEOGRAPHIC TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards Specifications OPSS 1002, 1988 and 1003, 1988)

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix B — Glossary

Abrasion Resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption Capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desirable.

Alkali-aggregate Reaction: A chemical reaction between the alkalis of Portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing, or classification. Heavy media separation, jigging, or application of special crushers (e.g., "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical

weathering of a larger rock mass. Synonyms include particle and fragment.

Crushable Aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious Lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial landforms found in Ontario.

Gneiss: A coarse-textured metamorphic rock with the minerals arranged in parallel streaks or bands. Gneiss is relatively rich in feldspar. Other common minerals found in this rock include quartz, mica, amphibole and garnet.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm

Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granite: A coarse-grained, light-coloured rock that ordinarily has an even texture and is composed of quartz, and feldspar with either mica, hornblende or both.

Granular Base and Subbase: Components of a pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as, support for surfacing materials. Four types have been defined: Granular A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular B which is usually pit-run or other unprocessed aggregate, Granular M is a shouldering and surface dressing material with quality requirements similar to Granular A, and Select Subgrade Material has similar quality requirements to Granular B and it provides a stable platform for the overlying pavement structure. (For more specific information the reader is referred to Ontario Provincial Standard Specification OPSS 1010).

Hot-laid (or Asphaltic) Aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (HL 1, 3 and 4), or as binder course (HL 2 and 8) used to bind the surface course to the underlying granular base.

Lithology: The description of rocks on the basis of such characteristics as colour, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35 percent indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45 percent indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium Sulphate Soundness Test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to

15 percent indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater Channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Petrographic Examination: An aggregate quality test based on known field performance of various rock types. In Ontario the test result is a Petrographic Number (PN). The higher the PN the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abrasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible Resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT) These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K) Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E) Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers, consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by

better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC) This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW) Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Subaqueous Fan (SF) Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment-laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan- or lobe-shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels which may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay which settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

Alluvium (AL) Alluvium is a general term for clay, silt, sand, gravel or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have

generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB) These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of Ontario. Well developed lacustrine beaches are usually less than 6 m thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD) These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP) The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in

relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular subbase aggregate.

GLACIAL DEPOSITS

End Moraines (EM) These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD) Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

Appendix D — Aggregate Quality Testing

Four types of aggregate quality tests have been performed on selected samples from the project area. A description and the specification limits for each test are included in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The above four types of tests were performed by the Ontario Ministry of Transportation.

Absorption Capacity Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate. This test is conducted in conjunction with the determination of the sample's relative density.

Los Angeles Abrasion and Impact Test This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can

be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35 percent indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45 percent indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium Sulphate Soundness Test This test is designed to simulate the action of freezing and thawing on aggregate. Those aggregates which are susceptible will usually break down and give high losses in this test. Values greater than about 12 to 15 percent indicate potential problems for concrete and asphalt coarse aggregate.

Petrographic Examination Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

TABLE D1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

TYPE OF MATERIAL	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
	Petrographic Number Maximum	Magnesium Sulphate Soundness Maximum % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular A	200	-	-	60	-
Granular B Type I	250*	-	-	-	-
Granular M	200	-	-	60	-
Selected Subgrade Material	250	-	-	-	-
Surface Treatment Class 1	135	12	1.75	35	-
Surface Treatment Class 2	160	15	-	35	-
Surface Treatment Class 3	160	12	2.0	35	-
Surface Treatment Class 4	-	-	-	-	20
Surface Treatment Class 5	135	12	1.75	35	-
Hot Mix - HL 1	100	5	1.0	15	16
Hot Mix - HL 2	-	-	-	-	20
Hot Mix - HL 3	135	12	1.75	35	16
Hot Mix - HL 4	160	12	2.0	35	20
Hot Mix - HL 8	160	15	2.0	35	20
Structural Concrete, Sidewalk, Curb, Gutter and Base	140	12	2.0	50	16
Pavement Concrete	125	12	2.0	35	16

* requirement waived if the material has more than 80% passing the 4.75 mm sieve

(Ontario Provincial Standard Specifications OPSS 304, OPSS 1002, OPSS 1003 and OPSS 1010)



CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	Multiplied by	Gives	Imperial Unit	Multiplied by	Gives
LENGTH					
1 mm	0.039 37	inches	1 inch	25.4	mm
1 cm	0.393 70	inches	1 inch	2.54	cm
1 m	3.280 84	feet	1 foot	0.304 8	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	1.609 344	km
AREA					
1 cm ²	0.155 0	square inches	1 square inch	6.451 6	cm ²
1 m ²	10.763 9	square feet	1 square foot	0.092 903 04	m ²
1 km ²	0.386 10	square miles	1 square mile	2.589 988	km ²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm ³	0.061 02	cubic inches	1 cubic inch	16.387 064	cm ³
1 m ³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m ³
1 m ³	1.308 0	cubic yards	1 cubic yard	0.764 555	m ³
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L
MASS					
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 908 8	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practices Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

**MAPS
NOT
FILMED**

**CARTES
OMISES**